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The neuroscience of social comparison and competition

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Abstract

The study of competition from a social comparison perspective offers valuable insights into the neuroscience of social judgment and decision making under uncertainty. When engaging in social comparison, individuals seek and assess information about similarities or differences between others and themselves, in large part to improve their self-evaluation. By providing information about one's relative position, abilities, outcomes, and more, social comparisons can inform competitive judgments and decisions. People reasonably turn to social comparisons to reduce uncertainty before, during, and after competition. However, the extent to which they do so and the behavioral consequences of social comparisons often fail to match the potential benefits of improved self-evaluation. An examination of the developing neuroscience of social comparison and competition in light of the behavioral evidence reveals numerous questions that merit further investigation.

Keywords Social comparison · Competition · Uncertainty · Self-evaluation · Upward comparison · Downward comparison · Neuroscience

Social comparison research has developed since the middle of the 20th century from early social psychological work on level of aspiration, informal social communication, and more (Wheeler & Suls, 2020). During the same period, behavioral decision research, with its foundations in the fields of preferential choice and judgment, has experienced comparable growth (Goldstein & Hogarth, 1997), but the two fields have exerted little impact on one another (Kruglianski & Mayseless, 1990). Nonetheless, the expansive social comparison literature and, in particular, the study of competition from a social comparison perspective offers insights into comparative social judgment and related decision making under uncertainty, with significant neuroscience implications.

Specifically, the findings discussed here illustrate how individuals routinely turn to social comparison—an adaptive, relatively efficient, and potentially rational judgment process—to improve their self-evaluation (Bentiez & Bronson, 2020; Corcoran & Mussweiler, 2010; Mussweiler, 2003), particularly in the face of competition (Garcia, Reese, & Tor, 2020). At the same time, however, decision makers also exhibit systematic biases when searching for and judging competitive social comparison information (Dunning, 2023). Moreover, although social comparisons can enable better competitive decisions, the factors that variously facilitate and inhibit social comparison also shape individuals' competitive behavior in ways that are unlikely to benefit them (Garcia & Tor, 2009; Garcia et al., 2005). Finally, and importantly, these behavioral findings also bear significant neuroscientific implications that more recent studies of the neural correlates of social comparison and competition have only begun to unravel (Kedia et al., 2014; Luo et al., 2018; Swencionis & Fiske, 2014; Yaple & Yu, 2020).

This review opens by defining "social comparison" and presenting illustrative findings on its role as a means for self-evaluation—a fundamental process of social judgment and decision making. We follow by clarifying our usage of the term "competition," setting the stage for the appraisal of the interplay between social comparison and competitive judgment and decision making under uncertainty. This appraisal draws on two related frameworks that organize the behavioral evidence in this area (Garcia et al., 2013; Garcia, Reese, & Tor, 2020; Garcia & Tor, 2023), considering in turn the role of the social comparison process before, during, and after competition and demonstrating how this process can variously promote effective behavior or contribute

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to biased judgments and questionable decisions at each of the three stages of competition. Finally, we examined in detail the developing neuroscience of social comparison and competition, relating its findings to the frameworks and evidence provided by the broader behavioral literature. This exercise brings the progress and limitations of extant neuroscience research in this area into sharp relief and reveals numerous avenues for fruitful neuroscientific research at the intersection of social comparison and competition.

Social comparison and self-evaluation

We begin by defining "social comparison" and highlighting its central self-evaluation function and the basic question of comparison direction, before turning in the next section to the role of social comparison in competition.

Defining social comparison

In plain English, "social comparison" could denote any comparison among individuals or groups in society—an intuitive meaning that may have contributed to the ambiguity of the term and the multiplicity of definitions offered by the literature in the field (Wheeler & Suls, 2020; Wood, 1996). Notwithstanding this confusion, both Festinger's (1954) early formulation and the bulk of the social comparison research that followed revolve around the "essential or core feature" of the process of thinking about others in relation to the self (Wood, 1996, p. 520). Accordingly, we refer to social comparison as shorthand for *the various processes through which individuals learn of self-relevant social information and make judgments or decisions based on that information*.

When engaging in social comparison, people seek, assess, or act upon self-relevant information about similarities or differences between others and themselves. In this respect, social comparisons are only one important form of comparative thinking among the various forms that individuals employ in their judgment processes (Kahneman & Miller, 1986). Importantly, researchers have long established *self-evaluation*—that is, self-judgment under uncertainty—as a central function of this comparison-based judgment and decision behavior (Festinger, 1954; Gruder et al., 1975).

Self-evaluation

Social comparisons can offer information regarding one's relative position, abilities, performance, and more, which can be used to improve self-evaluation and related judgments and decisions (Suls & Wheeler, 2020). For instance, individuals may use social comparisons the better to assess how intelligent they are, how good they are at a particular task (e.g., as medical doctors), or how likely they are to achieve a given goal (e.g., save enough money to buy their first home).

But *when* do people turn to social comparisons to inform such judgments? Insofar as social-comparison is an adaptive, efficient cognitive process (Bentiez & Bronson, 2020; Corcoran & Mussweiler, 2010; Mussweiler, 2003), we should expect individuals employ this low-cost and widely available source of social information when it offers the greatest benefits. The following section describes two sets of findings—on the related roles of target similarity and information diagnosticity in self-evaluation—that fit the efficiency account of social comparison well.

Target similarity

Festinger's (1954) early work hypothesized that individuals' tendency to engage in social comparison to self-evaluate opinions or abilities depends on the *similarity* between the targets available for comparison and oneself. Specifically, he argued that "[i]f some other person's ability is too [divergent]…it is not possible [for the actor] to evaluate his own ability *accurately* by comparison with this other person" (Festinger, 1954, p. 120; emphasis in the original). Because individuals strive to increase the accuracy of their self-judgments by comparing to others, their comparison targets must be sufficiently similar to them to provide meaningful information. Absent similarity, "the person will not be able to make a subjectively precise evaluation of his opinion or ability" (Festinger, 1954, p. 121).

The wide-ranging literature that followed Festinger (1954) grappled with numerous questions raised by this early hypothesis. Wheeler and Suls (2020, p. 8) note that determining the precise meaning of the necessary similarity between the actor and the comparison targets "produced the greatest problem for social comparison theory." Similarity was conceptualized in at least three distinct and increasingly broad ways, from similarity on the specific attribute to be evaluated (e.g., tennis ability), to similarity on other attributes that are related to the evaluated attribute (e.g., physical conditioning or training), to a loose notion of similarity on any attribute.

One notable stream of social comparison research that developed the second meaning of the similarity concept was started by Goethals and Darley (1977). They offered what became known as the *related attributes hypothesis*, suggesting that people will choose among the targets available for comparison based on these targets' "standing on characteristics *related to and predictive* of performance or opinion" (Goethals & Darley, 1977, p. 265; emphasis added). This work and the many studies that built upon it were therefore premised on the notion that people can improve their self-evaluations under uncertainty by seeking social comparison information about targets whose similarity on other, related attributes rendered them likely to resemble the actor on the attribute of interest.

Other research that examined related attributes corroborated Goethals and Darley's (1977) basic hypothesis. For instance, studies that manipulated related attributes demonstrated their role in the selection of comparison targets, beginning with Zanna, Goethals, and Hill's (1975) well-known manipulation of gender as an attribute (fictitiously) related to intellectual ability. Other experiments that manipulated factors, such as age, sex, or past practice, on a given task as performance-related attributes followed (Suls & Wheeler, 2020).

Information diagnosticity

The requirement of target similarity for social comparisons to fulfill their self-evaluative function also highlights a more general point—namely, that for such comparisons to improve self-judgment under uncertainty the information they provide should be *diagnostic* (Gruder, 1977). Ideally, to avoid confounds in causal inferences from social comparison information, a target should resemble the actor on all performance-relevant attributes. More realistically, however, given the paucity of such ideal targets, researchers predicted that people's confidence in their self-evaluation will depend on the informativeness of their social comparisons.

The role of information diagnosticity was suggested by early studies on the self-evaluation of abilities under uncertainty, such as those of Jones and Regan (1974). In the first of two studies, participants sought comparison information about their ability level more before making a decision about an action based on that ability (choosing the difficulty level of a test with payoffs depending on difficulty and performance) than when they could obtain the same information after they made their decision. In other words, participants unsurprisingly valued social comparison information more when it was potentially useful for making their ability-based decision than otherwise. In a similar vein, a second study found that the participants' preference for interacting with similar-ability individuals (as opposed to dissimilar ones) was stronger when those similar targets already performed the task at hand (Jones & Regan, 1974).

Evidence of the importance of information diagnosticity also emerged from further studies of the related-attributes hypothesis. When making inferences from related attributes, decision makers must be able to attribute their targets' observed performance differences to relevant differences in ability rather than to other, less relevant, performance-related attributes (Goethals & Darley, 1977). Such comparisons may offer diagnostic information to the extent that a target differs from the decision maker on related attributes that contribute to performance differences (Smith & Arnkelsson, 2000). In line with this prediction, Gilbert et al. (1995) found that participants discounted ability differences as a cause of differences in performance, when informed that the comparison target received training on the task (that participants did not receive) or that the task that the target performed had a difficulty level that differed from that of the participants' task.

Related-attributes research also offers some limited direct evidence on the relationship between the diagnosticity of social comparison information and decision makers' confidence in their self-judgments. For example, Arnkelsson and Smith's study (2000) found that participants' confidence in their self-judgments based on relative performance comparisons on an unfamiliar ability ("complex information processing") depended on their target's standing on an attribute that was previously described as performance-related (e.g., one's occupation).

Comparison direction

Finding that individuals seek to improve their self-evaluation under uncertainty by obtaining diagnostic information through comparisons to similar others still leaves open a basic question that occupied a significant portion of the literature—that is, whether and when people seek upward comparisons (to better-performing or more experienced targets) versus downward comparisons (to worse-performing or less experienced targets). In principle, a comparison to similar others under uncertainty can yield either upward or downward comparison information, as we discuss further in the context of social comparisons after the competition. However, the large majority of the studies that examined the choice of comparison targets found that individuals tend to seek upward comparisons—specifically, those that offer information about the performance of slightly-superior others (Suls & Wheeler, 2020).

The notion that people actively seek downward comparisons as a means for self-enhancement when they are psychologically threatened gained significant popularity for about two decades beginning in the early 1980s, led by the Downward Comparison Theory of Wills (1981). However, despite the intuitive appeal of this theory, further studies found limited evidence for its main claim (Suls & Wheeler, 2020). In addition, late 1980s research complicated the picture by demonstrating that both upward and downward comparisons can produce either positive or negative affect, challenging the notion that self-enhancement is reliably served by downward comparisons (Buunk et al., 1990).

Most significantly for present purposes, a recent meta-analysis of more than 60 years of social comparison research found that, overall, people strongly favor upward over downward comparisons (Gerber et al., 2018). This finding supports the central function of social comparison as a means for self-judgment under uncertainty.

Social comparison and competition

Having outlined the basic contours of social comparison's self-evaluation function, we turn our attention to its operation in competition. Our focus on this key arena of social behavior allows us to demonstrate both the value of social comparisons as a means for obtaining and assessing self-relevant information under uncertainty and their associated judgment biases and decision errors.

Defining competition

Even more than in the case of social comparison, the term "competition" is widely used in everyday discourse and has a broad range of meanings. Typical dictionary definitions focus either on the *act or process of vying for outcomes* or on *institutional settings that pit competitors against one another* (Garcia, Reese, & Tor, 2020). Common definitions of competition in social science similarly emphasize its overt, objective features, which produce a zero-sum interaction whose outcome establishes winners and losers based on something beyond pure chance (Bronson & Merryman, 2014; Roth, 2016). The competitions covered by such definitions include numerous social arrangements and institutions, from athletic contests to games of all forms, through school admissions, job markets, bids and auctions, and much more.

Yet the *psychological* study of competition is primarily concerned with decision makers' behavior and their feelings, perceptions, motivations, and intentions rather than with their objective institutional arrangements. For this reason, we define competition here broadly as including *any manifestation of individual competitive behavior or a competitive psychological state*, even when such behavior or state occur outside explicitly competitive interactions or competitive institutional arrangements (Garcia et al., 2023). After all, individuals can experience competitive feelings or motivations, or even act competitively, in circumstances that are not inherently, structurally, competitive (e.g., situations that only one party perceives as competitive (Graf-Vlachy et al., 2012) or interactions between rivals in which their objective outcomes are independent of one another (Garcia & Tor, 2023).

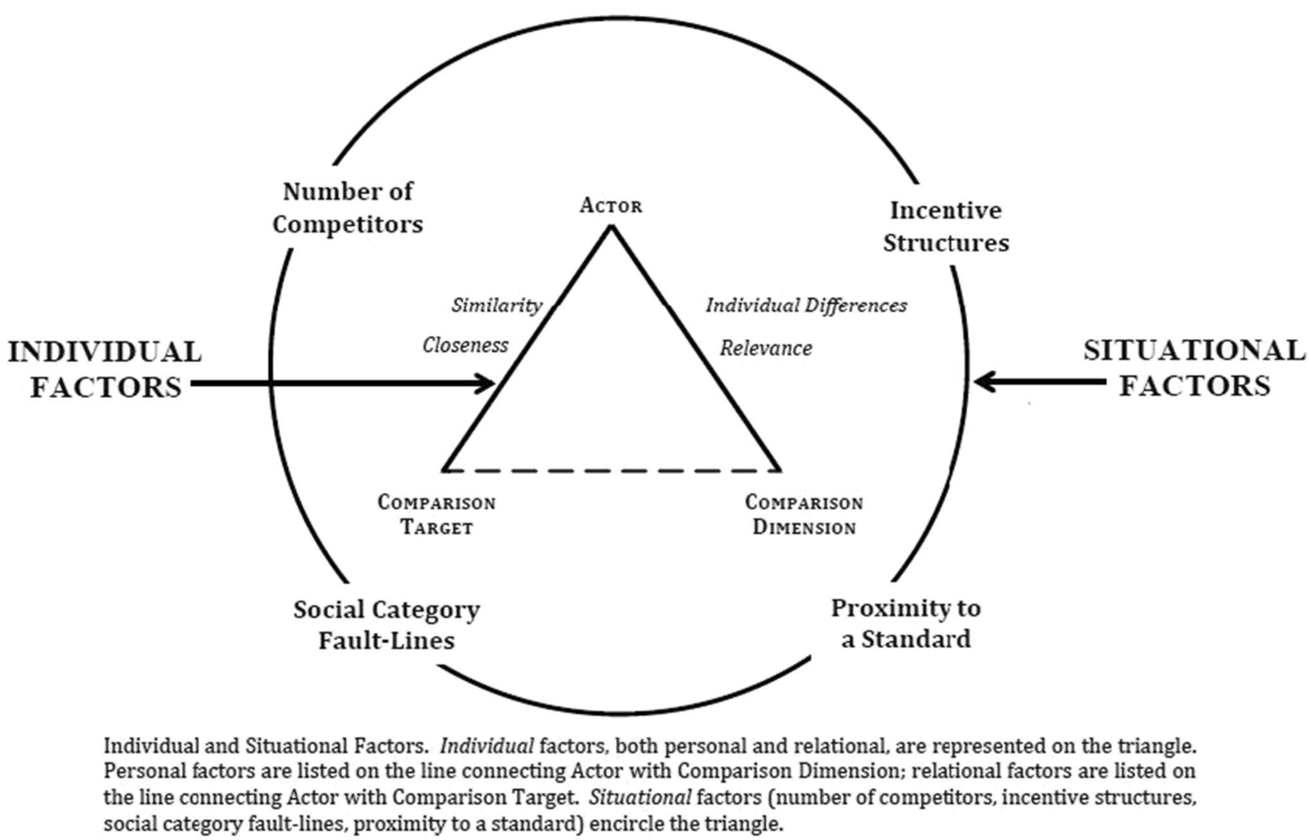

Fig. 1 The social comparison model of competition. *Note*: This figure was developed from the authors' earlier work in Garcia et al., 2013

Table 1 The social comparison cycle of competition—factors, processes, and biases

	BEFORE COMPETITION: Whether to Compete	DURING COMPETITION: How to Compete	AFTER COMPETITION: Performance Evaluation
ILLUSTRATIVE FACTORS AND PROCESSES	Individual Factors *Individual Differences* - Competitiveness - Social Comparison Orientation	Individual Factors *Individual Differences* - Performance vs. Mastery Goals *Dimension Relevance* *Relational Factors* - Relationship Closeness - Rivalry Situational Factors - Incentive Structures - Proximity to a Standard - Number of Competitors (N) - Social Category Fault Lines	Comparison Direction - *Upward Comparison* - *Downward Comparison* Competition Re-Entry Decision Individual Factors *Individual Differences* - Fixed vs Growth Mindset Situational Factors - Incentive Structures
ILLUSTRATIVE BIASES	Illusory Superiority	Overpowering Effect of Social Comparison Information *N*-Effect Irrelevant Self-Categorization	Comparison Direction Preferences (?)

Frameworks

Social comparisons serve decision makers' general need for self-evaluation, but play a particularly important role under competition, when outcomes are determined by competitors' relative performance and uncertainty is pervasive. Such comparisons shape competitive judgment and decision behavior in a number of ways that are best understood using two related frameworks for studying the social comparison—competition interface.

The first of these frameworks is the basic Social Comparison Model of Competition (Garcia et al., 2013), which accounts for the role of *individual* and *situational* factors in shaping social comparison concerns and thus competition. Individual factors depend on a given actor's identity and vary among decision makers, encompassing both *personal* factors that pertain to an actor's personal preferences and inclinations and *relational* factors that concern how a decision maker relates to a specific competitor. Situational factors, on the other hand, are features of the social comparison landscape within which decision makers compete and therefore tend to exert a comparable effect on similarly situated individuals. See Fig. 1.

The second framework is the Social Comparison Cycle of Competition, which considers the dynamic operation of social comparison before, during, and after competition (Garcia, Reese, & Tor, 2020).

Drawing on these two models, we describe the factors that affect people's self-evaluation before competition and their decisions regarding whether to enter competitions or otherwise act competitively. We then show how social comparisons shape motivation and performance during competition and conclude this section by explaining the factors that affect social comparison and judgments of outcomes *after competition*. Within each section, we also highlight the biases that are likely to emerge and affect competitive judgements and decisions. Table 1 summarizes the factors, proccesses, and biases highlighted by the Social Comparison Cycle of Competition elaborated below.

Before competition: deciding whether to compete

Uncertainty is common before competition, when individuals may possess only limited information about their prospects. Potential competitors face this challenge when considering whether to partake in formally organized competitions, such as a long-distance race or chess match (Baimbridge, 1998; Kringstad & Gerrard, 2004). Uncertainty often is greater when the prospective competition is informal and thus lacking precisely defined rules or structure, a public record of past performance, or official rankings (Bylund & McCaffrey, 2017; Goel et al., 2022). This is the case, for instance, with many everyday competitive social interactions in the workplace, the classroom, within a circle of family or friends, or on social networks (Bronson & Merryman, 2013; de Botton, 2008; Kohn, 1992).

Social comparison information can provide invaluable information that reduces this competitive uncertainty. For example, building on the related-attributes hypothesis (Goethals & Darley, 1977), the proxy model of social comparison (Wheeler et al., 1997) describes the conditions under which actors use different pieces of social comparison information, such as attributes they share with competitors, to predict their own performance. To illustrate, when considering a swimming competition in the absence of information about a competitor's swimming ability, one might predict their prospects based on related attributes that are relevant to success in the competition, such as gender, fitness, age, or training. A greater similarity between the self and the prospective competitor with respect to these attributes would predict a more difficult competition. A greater dissimilarity, on the other hand, would lead to an expectation of an easy win or an easy loss, depending on the direction of the comparison.

Notably, while the information provided by social comparisons shapes the decision of whether to enter competitions, the reverse is true—that is, individuals sometimes choose to compete to generate social comparison information that may improve their self-evaluation more generally (Trope, 1986). For example, performance on a specific competitive task (e.g., when fair visitors throw balls into a hoop) can become a proxy measure that provides information about one's comparative standing on a more significant general scale (i.e., eye-hand coordination or athletic skill) rather than merely with respect to the specific task (Garcia & Tor, 2007). On such occasions, the need for self-evaluation may drive individuals to enter competitions to produce social comparison information (Garcia, Reese, & Tor, 2020).

Individual factors

Research has pointed to some individual differences—a personal (individual) factor—that are associated with the search for social comparison information and decision makers' related propensity to enter competitions. Specifically, studies suggest that those who are motivated by personal development goals seek competition to uncover information that helps them the better to judge their level of competence, which they also seek to improve via competition (Bonte, Lombardo, & Urbig, 2017; Newby & Klein, 2014). For example, in developing the Competitive Orientation Measure, Newby and Klein (2014) identified *personal enhancement competitiveness* as one of their Measure's factors that is based on the following items: "I can improve my competence by competing"; "Competition allows me to measure my own success"; "Competition allows me to judge my level of competence"; and "I use competition as a way to prove something to myself" (p. 888, Newby & Klein, 2014).

These findings echo the evidence on the self-evaluation role of social comparisons. In particular, individual differences in social comparison orientation (SCO)—namely, the extent to which individuals have an interest in comparison information regarding the abilities and opinions of others in relation to their own (Gibbons & Buunk, 1999)—have been linked to individual differences in competitive behavior. For instance, researchers (Liu, Z. et al., 2021) have recently examined the link between social comparison orientation and trait competitiveness, finding that ability-related SCO is a significant predictor of trait competitiveness, as well as of overall risk-taking (e.g., gambling or health/safety behavior).

Similarly, the two-factor model of competitiveness (Houston et al., 2002) measures individual competitiveness based on the social-comparison related factors of "self-aggrandizement" (measured by statements like "I want an A because that means I am better than other people") and "interpersonal success" (measured by propositions, such as "I like competition because it teaches me a lot about myself"). The latter factor specifically is concerned with acquiring social comparison information to improve one's self-evaluation under uncertainty.

In fact, individual differences in this area are sufficiently strong that people with high trait competitiveness may perceive a noncompetitive situation as a competitive one (Reese et al., 2022). For example, in a recent study, sales agents reported that they would feel a stronger "desire to win" when a sales position was competitive (i.e., salary based on commission) than when it was noncompetitive (i.e., salary is fixed), but those among them who scored high in trait competitiveness were more likely to express a strong "desire to win" even when the position was noncompetitive (Reese et al., 2022).

Thus, individuals may engage in the same processes of acquiring and assessing social comparison information when they subjectively find the situation competitive, irrespective of its objective noncompetitive character or whether the targets of their comparison perceive it as.

Biases

Importantly, although decision makers may seek social comparison information to improve their self-evaluation when deciding whether to compete, the literature is replete with evidence of judgmental biases that affect such comparisons. For one, a majority of individuals thinks that they are better than average (for a recent review, see Zell et al., 2020), an obvious statistical impossibility (Dunning, 2011; Kruger & Dunning, 1999). Recently, Dunning (2023) dubbed these general effects *illusory superiority*, as people see themselves better than others across many domains (Alicke & Govorun, 2005; Dunning et al., 2004; Dunning, 2023). To cite some well-known examples, 94% of college professors claim they do above-average work (Cross, 1977); business executives believe their respective firms are more likely to succeed than the average firm (Cooper et al., 1988); and 32% of engineers working at a Silicon Valley firm thought that their skills were among the top 5% (Zenger, 1992).

Illusory superiority also manifests in competitions. For example, chess and poker players believe that they will advance further in tournaments than they actually do (Park & Santos-Pinto, 2010), and lawyers in the adversarial court systems believe that they will meet their minimum goals for the cases they litigate at greater rates than they do in fact (Goodman-Delahunty et al., 2010; see also Loftus & Wagenaar, 1988). Similar effects obtain in the world of start-up companies: many new enterprises are founded but a large margin of them fail within a few years (Dunne et al., 1988; Mata & Portugal, 1994; Tor, 2002; Wagner, 1994).

Illusory superiority similarly has been demonstrated in an economic experiment that examined individuals' decisions of whether to enter a competition (Camerer & Lovallo, 1999). Participants in this study were told they would be ranked from highest to lowest but would not know their rank. They then needed to decide whether to enter a competition whose outcomes depended on these unknown ranks, knowing only the maximum number of participants who would be guaranteed a positive payoff if they entered, so long as the overall number of entrants did not exceed that maximum number allowed. If the number of entrants exceeded the allowed maximum, those with lower rankings beyond that maximum would lose money.

Across various rounds of the game, participants were informed that the rankings were based on either a random number generator or an underlying assessed skill (i.e., performance on a quiz). Results showed that when the ranks were determined at random, participants generally matched the optimal number for all to win, and the group as a whole profited above what they would have received had they not entered the competition. However, when rankings were determined by underlying skill, too many participants entered the competition, leading to an average loss compared with what they would have received had they not entered. These results illustrate how *illusory superiority* appeared once rankings were skill-based and therefore amenable to self-serving biases in social comparison (Dunning, 2023).

During competition

When individuals find themselves already in competition, they often seek social comparison information to inform their self-evaluation and competitive decision making. Many of the factors that shape social comparison processes and competitive behavior within such environments match the anticipated self-significance of competitive outcomes or with the uncertainty-reducing benefits of social comparison (though to date there has been little direct study of these associations). Moreover, the factors of social comparison can impact competitive behavior even when further attention to comparisons provides neither better nor more self-relevant information (Garcia et al., 2013; Garcia, Reese, & Tor, 2020; Garcia & Tor, 2023).

Individual factors

We illustrate the effects of individual factors, which vary among similarly-situated individuals, with the personal factors (that concern characteristics of decision makers and their relationship to the comparison dimension) of individual differences and dimension relevance and the relational factors (that concern the relationship between decision makers and their comparison targets) of closeness and competitive history (Garcia et al., 2013).

Individual differences impact social comparison during competition, much as they do before competition. For example, individuals with performance-related goals—which naturally involve outperforming others—engage in social comparison more than individuals with mastery goals, who are primarily concerned with improving their personal skills (Darnon et al., 2012; Summers et al., 2003).

Similarly, dimension relevance—that is, the degree to which a person considers a particular performance dimension relevant to their self-definition—is a well-established personal factor. As Tesser (1988, p. 4) explained, "A dimension is important to an individual's self-definition to the extent that he strives for competence on the dimension, describes himself in terms of the dimension, or freely chooses to engage in tasks that are related to the dimension." As the relevance of the dimension increases, the concern for social comparison on that dimension also increases. A scholar, for instance, is more likely to be concerned about how her performance compares to others with respect to her academic research (e.g., the number and placement of scholarly publications) than with respect to her tennis game. More generally, decision makers exhibit a stronger tendency to seek and attend to social comparison information when the dimension on which competition takes place is more self-relevant.

The importance of relational factors—such as the previously discussed similarity between decision maker and comparison target—in making social comparisons more informative is clear. Yet relational factors can also affect social comparison because they indicate that a target is more self-relevant. To illustrate, research documents how relationship closeness can facilitate social comparison and competitive behavior. For example, individuals have been shown to act more competitively toward their friends—giving them more difficult clue words in a game of Password—than toward strangers (Tesser & Smith, 1980). That social comparison and competition increase in close relationships also helps explain findings such as those concerning people's unwillingness to befriend those who signal that they have higher status (Garcia et al., 2019).

In a similar vein, research shows that a history of competitive interactions can also render social comparisons particularly important to decision makers, giving rise to ongoing rivalries (Kilduff et al, 2010; for a review, see Converse et al., 2023) that involve an increased motivation to compete (Kilduff, 2014). These patterns are echoed by studies showing fans of rival sports teams citing the teams' shared history in free response accounts of why it was important to beat the rival (Converse & Reinhard, 2016). Indeed, match-ups between rivals often involve not only the "tangible stakes" at hand but also higher level of "psychological stakes" (Kilduff et al., 2010).

Situational factors

We illustrate how situational factors affect the importance of social comparison in competitive settings with findings on the effects of incentive structures, proximity to a standard, the number of competitors, and social category fault lines (see generally Garcia et al., 2013).

Some situational factors—such as incentive structures—are directly related to the significance of the competition to the decision maker. When a competition involves higher payoffs, individuals manifest heightened social comparison concerns and competitiveness (Cole, Bergin, & Whittaker, 2008; Isaac & James, 2000). A similar dynamic takes place when the competition is a "zero sum" one, in which every gain to one party is a loss to another (Bazerman et al., 2001; Lawler, 2003; Mittone & Savadori, 2009), an incentive structure that renders social comparison particularly informative and thus, unsurprisingly, heightens social comparison concerns.

Yet, situational factors can increase the self-relevance of competitors' social comparisons in less obvious or direct ways. To illustrate, studies show that competition and social comparison concerns intensify in the proximity of standards—that is, of meaningful qualitative thresholds—such as the bottom or the top of a ranking scale (Garcia & Tor, 2007; Hamstra and Schreurs, 2018; Vriend et al., 2016). Thus, competitors are less willing to maximize joint gains when they have high or bottom rankings than when they hold intermediate ranks (Garcia & Tor, 2007).

These findings have been linked to increases in social comparison concerns and competitiveness (Garcia & Tor, 2007; Garcia et al., 2006). For example, participants in one study reported that they would feel more pain in social comparison and more competitiveness toward their rival when they and the rival were highly ranked (proximate to the #1 standard) than when they were not (Garcia et al., 2006). In another study, researchers asked Major League Baseball fans to imagine being a team manager. The fans reported more social comparison concerns over how their team stacked up against a rival team—measured by adapted items from the social comparison orientation scale (Gibbons & Buunk, 1999)—when both teams were highly ranked than when they were intermediately ranked (Garcia, Arora et al., 2020).

The relevance of the proximity to a standard for competitive decision makers is to be expected in many common circumstances, because material and reputational payoffs often are disproportionally greater for those who are very highly ranked compared with those of more intermediate ranking. Similarly, falling below a threshold (e.g., below #500 on the Fortune 500) can entail significant consequences. Irrespective of payoff differences, moreover, the value of the same change in ranking may be greater at the tail of a distribution than nearer its center. Rank differences may entail substantial absolute differences along the competitive dimension in the former location but only minor absolute differences in the latter location. Indeed, participants in Garcia et al.'s (2006) studies stated it was more important to do well and that differences among adjacent ranks were greater at high rankings compared with intermediate ones.

Another ubiquitous situational factor of social comparison and competition is the number of competitors (*N*). Studies show that individuals engage less in social comparison and become less competitive as the number of competitors increase even when expected payoffs are held constant, a phenomenon known as the "*N*-Effect" (Garcia & Tor, 2009; Tor & Garcia, 2010). In one study, participants were asked to complete an easy quiz as fast as they could without compromising accuracy and told that those in the top 10% of finishing time would receive a small cash prize. Results showed that participants completed the easy quiz significantly faster (without sacrificing accuracy) when they believed they were competing in a pool of 10 than when they believed they were competing in a pool 100 competitors (Garcia & Tor, 2009).

The *N*-Effect was linked to social comparison by studies showing that the concern for social comparison and competitive motivation decrease with *N* even when expected value remains constant (Garcia & Tor, 2009). Of course, the *N*-Effect goes beyond those common situations in increases in *N* diminish the expected value of winning and with it the incentive to compete and the self-relevance of competition (Boudreau et al., 2011; Casas-Arce & Martínez-Jerez, 2009; Ehrenberg & Bognanno, 1990; Ku et al., 2005).

Situational factors also can influence social comparison and competition in other subtle ways. For instance, social category fault lines emerge from the process of self-categorization, in which environmental cues lead individuals to categorize themselves into various social categories (e.g., ethnicity, gender, occupation, etc.) (Hogg, 2000). Research shows that individuals are more concerned with the consequences of competitions that occur across social categories—whose outcomes they may find more self-relevant—than with the outcomes of similar competitions that occur within a social category (). Hence, when making their choice across social categories, decisions makers are less likely to choose more profitable arrangements that produce better comparative outcomes for their counterpart (over less profitable but equal arrangements) than when making the same choice within a social category. For example, American participants in one study were asked to imagine being the CEO of American Airlines and consider a beneficial joint venture from which the venture partner would gain even more (Garcia et al., 2005). Results showed participants were less likely to recommend the venture across a social category fault line (with Air France) than when it was within the same social category (with Delta Airlines). Moreover, participants reported that the pain of upward comparison associated with American Airlines profiting less from the joint venture would be significantly higher in the across-fault-lines condition than in the within-fault-lines condition.

Biases

The various factors of social comparison shape self-judgments and decisions during competitions in ways that appear beneficial and adaptive, increasing social comparison concerns and competitive behavior when outcomes have greater self-relevance or when social comparisons are more informative. Nonetheless, a closer look reveals many effects of the same individual and situational factors on competitive judgment and behavior that hardly appear to benefit decision makers.

In the case of individual differences, for instance, we noted how decision makers with performance-related goals are more inclined than those with mastery goals to engage in social comparison in competitive settings (Darnon et al., 2012; Summers et al., 2003). Yet further research showed that interpersonal comparisons are so central to self-evaluation that even individuals with mastery goals can end up relying on this information over more goal-relevant information, such as temporal comparisons with their own past performance (Van Yperen & Leander, 2014). Such evidence illustrates the potentially "overpowering effect of social comparison information" that can misalign the standards decision makers employ to self-judge during competition, and perhaps even their resulting behavior, with their ostensible preferences.

The evidence on the impact of the situational factors of social comparison paints a similar picture according to which these factors can affect behavior during competition in ways that may not be beneficial, as exemplified here by research on the *N*-Effect and on social categorization. The biasing effect of *N* on social comparison and competitive behavior is particularly apparent, since the key evidence of this phenomenon already demonstrated that increases in the number of perceived competitors diminished social comparison concerns and, with them, competitive motivation or performance even while the expected value of winning remain constant as *N* diminishes (Garcia & Tor, 2009; Tor & Garcia, 2010). Moreover, some of the field evidence that corroborates the influence of the *N*-effect on real-world, competitive performance suggest that it can occur even when the number of immediate competitors that could be targeted for comparison (e.g., other test-takers who happen to take a standardized national test in the same testing location and on the same date) has little bearing on decision makers' competitive outcomes (Garcia & Tor, 2009).

The potentially biasing effects of social categorization are perhaps even more dramatic, given the highly malleable nature of the self-categorization process. Social categorization can manifest even when individuals' attention is directed to ad-hoc, temporary, or changeable categories of little substance or self-relevance, such as the (imaginary) "overestimators" and "underestimators" in the dot-estimation used in the famous early research on the minimal group paradigm (Tajfel, Billig, Bundy, & Flament, 1971).

Hence, though some social category fault lines—such as culture or nationality—can be very self-consequential, even insignificant or irrelevant social categories—like left- vs. right handedness or differing water-taste preferences—can affect decision makers' experiences and behavior in competitive settings (Garcia & Miller, 2007). Unsurprisingly, therefore, studies show that social categories can shape competitive behavior even when they have no bearing on the self-relevance of social comparison information, as differential payoffs to female vs. male students are randomly determined (Garcia et al., 2005).

After competition

As they do before and during the competition, individuals use social comparisons to learn from the outcomes of competition and improve their self-evaluation. Because of the limited literature in this study beyond the extensive research on decision makers' comparison direction preferences, we focus on the latter area, but also highlight relevant work on the propensity to reenter competition.

Comparison direction

Competitions may result in upward comparisons to those who outperformed oneself, downward comparisons to competitors who underperformed the decision maker, or a horizontal comparison to a competitor with similar performance. These different comparisons may help people to understand better the weaknesses and strengths of their performance, in line with the evidence showing individuals more generally turning to comparison information—particularly upward comparisons—as a means for self-evaluation. However, learning from social comparison appears subjective, and its lessons variable and often not particularly self-beneficial.

In particular, although upward comparisons can inspire future improvement (Higgins, 2011; Wood, 1989), they can lead to negative feelings, such as disappointment, dejection, or envy (Lange & Crusius, 2015; Montal-Rosenberg & Moran, 2023). Indeed, one central finding of the recent meta-analysis of more than 60 years of social comparison research was that upward comparisons produce overall contrast effects—significantly lowering decision makers' ability assessments and performance satisfaction (Gerber et al., 2018). This important result suggests that while individuals use social comparison information to learn from their relative performance, they also commonly experience upward comparison information as self-deflating.

Of course, decision makers who win competitions face downward comparisons with their fellow competitors, and even those who do not win may choose—as some competitors do—to compare to worse-performing rather than to better-performing competitors. Those less common downward comparisons can boost self-esteem (Brown et al., 2007; Gibbons & Gerrard, 1989) but also may increase vigilance and attention to the threat of being surpassed by others (Derks et al., 2016).

Competition reentry

After competition, when the resulting comparisons and their consequences have taken place, with the accumulated information from past performance (Brown et al., 2015), one might choose to enter a subsequent competition. In this context, decision makers can use social comparisons to assist in making attributions regarding their performance, including any successes and failures, as a basis for future competitive behavior (Festinger, 1954).

One individual factor studied in this area is whether a person possesses a fixed or a growth mindset (Dweck, 2007). Decision makers with fixed mindsets see their potential for performance as immutable, wholly dependent on natural ability, whereas those with growth mindsets see it as more changeable and subject to improvement with practice or instruction. Hence, if they perform poorly and thus face upward social comparison, decision makers with fixed mindsets are more likely to decide against reentering a competition, whereas those holding growth mindsets are more likely to reenter if only to improve or practice improving their performance.

We already noted that the literature to date has paid little attention to whether decision makers are more inclined to reenter competition after success (Garcia, Reese, & Tor, 2020). Nonetheless, some research suggests a role for the situational factor of incentive structures, reporting that individuals who perceive a realistic chance of winning a new competition after losing a previous one using the opportunity to re-enter as a means for repairing their self-views (Johnson, 2012).

Biases

The evidence on decision makers' preference for upward over downward comparisons (or the less-studied lateral comparisons) raises intriguing questions about the adaptive nature of these comparisons. As foreshadowed by Festinger's (1954) early work, the information provided by upward comparisons may allow for more accurate self-evaluation, so attending to it can be beneficial and adaptive even if it tends to lower self-assessment. Conversely, insofar as individuals typically find upward comparisons self-deflating, a preference for such comparisons may seem counterproductive (Gerber et al., 2018).

One possible explanation to this apparent tension between the preference for upward comparisons and their self-deflating reality is along the lines of our discussion of the biases underlying *illusory superiority* before competition. According to this view, decision makers who overestimate their abilities and prospects will underestimate the likelihood of a negative experience from an upward comparison. In the words of Gerber et al., (2018, p. 194): "[P]eople do not adequately anticipate the self-deflating contrast, or [believe] that the contrasts will be outweighed by other benefits. They think…that they will be able to assimilate themselves to a higher level, that they will learn the secrets of being better, and so forth."

Without dismissing this bias-based account, however, we should point out that, at least in competitive settings, the benefits of more accurate self-judgments may indeed exceed the costs of self-deflating contrasts. In fact, decision makers gain benefits far beyond the self-perception effects of their performance from participating in competitive interactions, including athletic or academic success, admission to selective institutions, workplace promotions and compensation, and more. In these and similar circumstances, many decision makers implicitly accept the high probability of facing contrastive upward comparisons, knowing they may still be better off for competing, comparing, and advancing their goals.

The developing neuroscience of social comparison and competition

Our review of the broader behavioral literature on social comparison demonstrated that social comparisons fulfill a central and often useful role in self-judgment and competitive behavior but also involve biased judgments and questionable decisions. The present section charts the emerging contours and findings of the neuroscientific study of social comparison and competition and then draws on our preceding review of the broader behavioral evidence in this area to clarify the lessons and limitations of these findings and raise a wide range of intriguing research questions for this developing field.

Emerging contours

The neuroscientific study of social comparison and competition is still in its early stages, but an examination of its emerging contours, methods, and research questions reveals both the potential and the limitations of current paradigms and the empirical findings that they generate.

While original research and reviews from the first half of the 2010s already assessed and integrated findings from dozens of neuroscience studies bearing on social comparison (Kedia et al., 2014; Lindner et al., 2015; Swencionis & Fiske, 2014), later reviews were able to meta-analyze a substantially larger volume of research. Thus, a July 2017 initial literature search for a meta-analysis of functional Magnetic Resonance Imaging (fMRI) research of social comparison identified approximately 100 relevant original studies (Luo et al., 2018).

Moreover, although fMRI studies have been the most common method employed in the neuroscientific study of social comparison, researchers employ a number of other methods, such as functional Near Infrared Spectoscopy (fNIRS) (Balconi & Vanutelli, 2016) and, increasingly, electroencephalograms (EEG) (Balconi & Vanutelli, 2016; Wang et al., 2018). In addition, some studies of competition use "hyperscanning"—the simultaneous fMRI scanning of two or more participants to record the cerebral activity of interacting brains (for a review, see Balconi & Angioletti, 2023).

Notably, irrespective of their methods, the neuroscientific studies considered here are relevant to the present analysis even though few of them explicitly focused on the role of social comparison in competition. This is the case not only because general evidence on social comparison processes also pertains to their specific operation in competition, but also due to the centrality of competition to common social environments that give rise to social comparisons. Neuroscience research sometimes uses objectively competitive tasks with interdependent payoffs (Lu et al., 2022). However, even studies with non-competitive payoffs (i.e., when participants' objective outcomes are independent of one another) frequently employ tasks, such as games (Wang et al., 2018) or lotteries (Bault et al., 2011; Dvash et al., 2010) that people associate with competitive behavior in everyday life or that rank experimental participants based on their (objectively independent) performance (Zink et al., 2008). Furthermore, the careful reader will have noted that these experimental designs often fit our capacious definition of competition as *any manifestation of individual competitive behavior or a competitive psychological state,* both within and outside objectively competitive settings.

Finally, it is important to recognize the advantages and limitations of the extant neuroscientific research. The obvious advantage of these studies is their ability to offer evidence on the neurological architecture of social comparison, which is not only important for its own sake but can also variously corroborate, refine, or challenge the theoretical constructs and findings of the long-standing behavioral literature in this area. At the same time, certain approaches employed by social comparison researchers can be challenging to implement with current neuroscientific designs. Consider, for example, the numerous behavioral studies that use the "selection method," in which experimental participants are exposed to (or given information about) multiple potential comparison targets, some superior and others inferior to the participant (Gerber et al., 2018). Such studies may seek to determine whether and when participants select upward or downward comparison targets, which of the available targets within a given comparison direction is selected (e.g., one nearer or one farther on the comparison dimension), which factors impact target selection, and more. This method is challenging to implement in current neuroscientific studies, however, which may account for the paucity of extant neuroscience selection studies.

Instead, as the findings detailed below make clear, neuroscientists typically use what social comparison researchers call the "reaction method" (Gerber et al., 2018). Neuroscientific reaction studies expose participants to comparison targets and measure their reactions to these targets as the dependent variable (Kedia et al., 2014; Luo et al., 2018; Swencionis & Fiske, 2014). This common approach is commensurate with the frequent use of the reaction method in behavioral social comparison studies, as evidenced by a recent meta-analysis that classified about two-thirds of the meta-analyzed studies as reaction method studies (with the balance classified as selection method studies) (Gerber et al., 2018).

Yet the natural reliance of neuroscientists on the reaction method bears implications for the type of research questions they examine and, no less importantly, for the questions they have not examined to date, a matter to which we return in detail after describing the emerging evidence in this area. For now, it suffices to note that the reaction method is less well-suited to studying the *before competition* stage, when decision makers decide whether or with whom to engage in social comparison, whether to act competitively or to enter a competition, and so on. Some neuroscience research could be characterized as studying social comparison *during competition* (e.g., the common use of multiperiod judgment or decision tasks; Bault et al. (2011); Fliessbach et al. (2007); Wang et al. (2018)). With some recent exceptions among EEG studies (Liu, S. et al., 2021), such reaction studies still focus on the immediate aftermath of participants' exposure to predetermined social comparisons or to the outcomes of the experimental task—namely, on the *after competition* stage.

We therefore first describe the developing research in this domain and only afterwards consider the lessons that can be gleaned from considering these findings on the backdrop of the constructs and evidence offered by the broader social comparison literature.

The significance of social comparison

At the most basic level, neuroscience research confirms the significance of social comparisons. Such comparisons have been found repeatedly to affect the brain's value-cording reward network—primarily the ventral striatum (VS), the ventro-medial prefrontal cortex (vmPFC), the anterior insula (AI), and the dorsal anterior cingulate cortex (dACC) (Kedia et al., 2014; Luo et al., 2018; Swencionis & Fiske, 2014).

In addition, reaction method studies demonstrate that decision makers' relative outcomes—the information targeted by the social comparison process—can produce a stronger activation of the reward system than absolute payoffs do, even when decision makers' payoffs depend only on their own performance (i.e., in objectively non-competitive interactions). This is illustrated by an early fMRI study employing what Kedia et al. (2014) call the classical experimental paradigm for studying the VS consequences of social comparisons. Fliessbach et al. (2007) had participants perform a dot-estimation task, following which they received feedback on their own performance and (after a short delay) another participant's performance together with information on both participants' respective monetary rewards. The study analyzed VS blood oxygen level–dependent (BOLD) responses, finding they strongly depended on relative payoffs, increasing with the ratio of participants' own rewards to those of their comparison targets, even while the main effect for high versus low absolute payments and its interaction with relative payment remained nonsignificant (Fliessbach et al., 2007).

Other studies of social comparison in objectively non-competitive tasks also show it can produce significant effects beyond those generated by absolute outcome levels. For example, Bault et al. (2011), who studied neural activity following the outcomes of independent lotteries chosen by participants, found higher mPFC activity following what they called a "social gain"—that is, when participants chose a lottery different from that chosen by their comparison targets and obtained a superior outcome—than in all other conditions, including those in which participants obtained the same absolute payoffs but without a social comparison or the comparison target obtained the same beneficial outcome.

An interesting recent EEG study by Wang et al. (2018) offers additional neural evidence on the motivating power of social comparison, according to which the mere possibility of social comparison can suffice to affect behavioral and neural measures in anticipation of task onset and during the task. Participants in this study faced a multi-trial stop-watch game that required them to estimate as accurately as possible the passage of time (3 s), followed by performance feedback. Game payoffs were for participation rather than performance and thus objectively noncompetitive (meaning that any observed effects were not due to incentives either). Participants were assigned to either a single-player condition or a two-player condition, in turn, with those in the latter condition having to choose immediately following each trial whether to obtain feedback on their performance alone or also on the performance of the second player, which participants chose to do in a slight majority of trials (56%).

Results showed enlarged stimulus-preceding negativity (SPN) and error-related negativity (ERN) in the two-player condition compared with the single-player condition, indicating increased anticipatory attention shortly prior to the game-onset stimulus and enhanced surveillance of performance during the trials. According to participants' self-reports, moreover, those in the two-player condition found the game more interesting and enjoyable, exerted more effort, and were more motivated to win. Nonetheless, actual performance in the two-player condition was only slightly and nonsignificantly better than in the single-player condition. (The reported data does not allow for examining whether participants who anticipated engaging later in social comparison outperformed their peers or otherwise differed systematically from those who avoided social comparison.)

Wang et al. (2018) suggest that their findings reveal the power of "contingent social comparison," according to which the availability of optional social comparison information on-demand generated the observed behavioral and neural effects indicative of increased motivation. Yet, a closer look reveals that the present design confounded the mere presence of a second player (a potential competitor, in the subjective, psychological sense) with the availability of and possible intention to use social comparison feedback. In other words, the observed effects may have been due to the mere presence of a co-actor, or some combination of this factor, and the possibility of social comparison factor advanced by Wang et al. (2018), so further research is required to disentangle the effects of the two factors.

Comparison direction

Turning to more specific aspects of social comparison, one finds that reaction studies have paid much attention to the neural correlates of downward versus upward comparison. This attention is reflected, for instance, in a recent pair of meta-analyses of fMRI studies that examined the brain regions showing involvement in comparisons in either direction, which collectively identified for inclusion 59 studies (Luo et al., 2018).

Downward comparison

Researchers found that the VS and vmPFC become activated when people compare themselves to others who are less fortunate or less successful (Bartra et al., 2013; Du et al., 2013), a result further confirmed by Luo et al.'s (2018) more recent meta-analysis of downward comparison based on 28 whole brain fMRI studies.

In one experiment, Dvash and coauthors asked participants to play with another putative participant a game of chance in which they had to guess which of three doors led to a gain or loss (ranging from + $4 to – $4) across multiple trials. After each trial, the participant completed a questionnaire regarding their emotions. The researchers found that participants who faced an absolute loss that still entailed a relative gain (compared with their counterpart's larger loss) experienced VS activation comparable to that of participants who experienced an absolute gain.

Other research that used objectively competitive paradigms—that is, experimental designs in which one party's gain is another's loss—similarly reported that the downward comparison that follows winning activates both the vmPFC and the VS (Beyer et al., 2014; Delgado et al., 2008), with one study further finding that outperforming a human competitor led to stronger responses in the vmPFC and VS than outperforming a computer opponent (Kätsyri et al., 2013). Moreover, another study that used a two-person competitive reaction-time task found similar VS activation not just when winning the competition entailed an absolute gain (in which case the competitor won nothing) but even when it entailed an absolute loss that was smaller than the competitor's loss and therefore still represented a downward comparison (Votinov et al., 2015).

Upward comparison

Neuroscientists have identified brain areas associated with upward comparison—that is, when decision makers face comparisons to others who are more fortunate or successful in their outcomes (Kedia et al., 2014; Steinbeis & Singer, 2014; Swencionis & Fiske, 2014). Numerous studies, as well as Luo et al.'s (2018) meta-analysis of 44 whole-brain fMRI studies, reveal that upward comparisons consistently activate the bilateral AI and the dACC.

To illustrate, Takahashi and colleagues (2009) asked student participants to imagine being a protagonist in a scenario that was average in terms of ability, quality, and social status. Participants then made comparisons to three other target students, one of which was superior, similar, and self-relevant (i.e., of the same gender, with similar attributes, and superior in terms of ability and quality), whereas two other less-similar and less-relevant comparison targets were either superior or similarly average. Results showed that envy ratings were higher and the dACC was activated when participants compared to the target that was both superior and relevant.

More recently, a pair of meta-analyses by Yaple and Yu (2020) that compared functional neural activity for social comparisons of status and monetary outcomes, respectively, largely corroborated the link between upward comparisons and brain regions associated with losses. Specifically, Yaple and Yu's (2020) meta-analyses found activity within the dorsal ACC, right and left insula, right angular gyrus, and right supramarginal gyrus for upward monetary comparisons, whereas upward social status comparisons exhibited a replicable cluster within the orbital frontal cortex/ventral ACC and a cluster within the dorsomedial PFC. In addition, a conjunction analysis found a cluster in the dorsomedial PFC for upward comparisons that was activated by comparisons in both domains, even while a contrast analysis found the two domains splitting such that monetary comparisons—which comprised the large majority of earlier studies—selectively engaged bilateral insula and dorsal ACC, whereas social status comparisons exclusively recruited OFC/ventral ACC, left superior occipital gyrus and posterior cingulate gyrus.

Self-evaluation

The developing neuroscience evidence appears to support the self-evaluative role of social comparison suggested by our review of the broader behavioral literature. Specifically, the brain regions associated with people's emotional responses to social comparison (Dvash et al., 2010) also are involved in reward learning.

Some fMRI studies that show VS involvement in representing social comparison information further suggest it can be used for learning and improving future decision making. For instance, Bault et al.'s (2011) study discussed above found that participants exposed to the performance of another player over multiple trials of a lottery-choice task showed increased activation of the mPFC and related regions associated with attributing mental states to others. This study also consistently exposed participants in earlier lottery-choice trials to manipulated comparison targets that made more risk-taking or risk-averse choices (with commensurate lottery payoffs). This manipulation turned out to shape participants' risk-attitudes in later trials, with those exposed to a more risk-taking target making riskier choices and vice versa for participants exposed to risk-averse targets. Notably, the researchers were able to trace this behavioral pattern to a brain network composed of the VS and mPFC, which can enable behavior adjustments based on the information obtained via social comparison and whose activity depended on whether participants had the opportunity to make such adjustments.

Other research that considered the learning properties of social comparison points to the role of the dACC in processing reward prediction and its errors (Takahashi et al., 2009), and further fMRI studies implicate other brain areas involved in social comparison. Luo et al., (2018, p. 446) suggest that because the VS, vmPFC, AI, and dACC all play a key role in encoding prediction errors in the course of general reward learning, their consistent activation in social comparisons identified by these authors' meta-analyses "might reflect prediction errors that signal the need for behavioral changes."

A simplified version of this account is that social comparisons may generate information that reveals decision makers' former predictions to be in error, with downward and upward prediction errors coded in different brain regions (the VS and vmPPC versus the AI and dACC), leading to different emotional reactions (positive versus negative), with negative feelings in particular motivating decision makers to change their behavior (Luo et al., 2018). Yet the contrast and conjunction of fMRI meta-analyses of Yaple and Yu (2020) discussed above, which found both overlapping and distinct brain networks associated with downward and upward social comparisons in monetary and social status domains, reveal a more complex picture.

In any case, the suggestive fMRI evidence regarding the self-evaluative function of social comparison also generated interest in EEG studies of the error signal produced by the dACC, which measure negative event-related potential (ERP) on the scalp. Several early ERP experiments tested whether feedback-related negativity (FRN)—a negative deflection at frontocentral scalp sites that peaks at around 200–350 ms following the onset of outcome feedback and tends to be stronger for negative feedback than for positive feedback (Kedia et al., 2014)—is modulated by social comparison. These studies, which used paradigms resembling those employed by fMRI research (i.e., objectively noncompetitive payoffs for performance on a dot-estimation task, with feedback provided on the outcomes of the participant and another actor), produced divergent FRN results. Boksem et al. (2011) found enhanced FRN in the face of upward comparison, whereas Qiu et al. (2010) and Wu et al. (2012) did not (results in the latter studies depended on the fairness of the payoff allocation, and even in that respect the two studies were inconsistent).

At the same time, Wu et al. (2012) found that social comparison modulated the P300—a centroparietal positivity that peaks in the period of 300–600 ms following feedback onset, which has been found more sensitive to positive than to negative feedback. This finding was again contradicted by Qi et al.'s (2018) report that social comparison does modulate the FRN without affecting the P300. The latter group of researchers, which used a three-person gambling task, found the FRN greater when participants faced an upward comparison with the two other players than when they did not (when all players received the same payoff). Further confusion was introduced by Valt et al. (2020), who presented outcome information to participants successively, starting with their personal outcomes and only then followed by social comparison information. Contrary to Qi et al.'s (2018) results, in this study social comparison did regulate a P300 component (P3a) associated with attention and memory, which was significantly larger for upward comparisons, implying that more attentional resources were allocated to them.

Recently, Liu, S. et al. (2021) sought to address the inconsistencies in the growing ERP literature by using an experimental design that modified the familiar dot-estimation task to produce actual ability comparisons among the participants (in terms of speed and accuracy). Participants' performance-based payoffs were independent of one another (determined by comparison to a fixed standard), yielding four comparison conditions (a two-by-two crossing of gain/loss by self/other). Results showed significant main effects of more negative FRN for both self-loss and other-gain (across conditions), as well as of a larger P300 for self-gain. Together, these results suggest that social comparison information may be processed at both the primary, semi-automatic, stage reflected in the FRN and the conscious, advanced, processing stage reflected in the P300. However, the former appears more concerned with upward comparisons (and absolute negative self-outcomes), whereas the latter responded to downward comparisons (as well as to absolute positive self-outcomes).

Individual factors

While specific brain regions have been associated with downward and upward comparisons, respectively, neuroscience research has occasionally employed designs that begin to shed light on the effects of the individual factors of social comparison—both personal and relational ones— identified by the broader behavioral literature, reviewed earlier.

For example, the scenario-based fMRI studies of Takahashi et al. (2009), which tested emotional reactions to upward and downward comparisons, sought to increase participants' brain activation in some conditions by describing comparisons on *more relevant dimensions*—a well-established *personal* factor—such as performance in an interview for a desired job or lifestyle qualities that are important to the scenario's protagonist, with whom the participants were asked to identify. In addition, in their effort to make some comparison targets more self-relevant, the researchers also heavily manipulated the *relational* factor of *similarity* (e.g., making one target a student of the same gender, with the same major, at the same university, a member of the same sports club, who previously attended the same high school, and has similar lifestyle preferences and hobbies as the protagonist). Because the manipulation modulated both self-rated envy scores and dACC activation (with the two positively correlated), this study illustrates the combined effect of two important individual factors of social comparison.

In another notable study, Moore et al. (2014) directly tested for the effects of similarity by asking experimental participants to provide the names of three similar and three dissimilar peers, whom they have known for at least 1 year and with whom they interacted regularly. During the study, participants were shown a series of trait adjectives and, in the two conditions of interest, were asked to compare themselves to similar and dissimilar peers. Results showed a significant effect of similarity in these conditions, with relatively more activity in vmPFC for social comparison with similar than with dissimilar peers.

In a similar vein, albeit using a real task and without manipulating these individual factors between subjects, Lindner et al.'s (2015) fMRI experiment encouraged participants to engage in social comparison in a noncompetitive task that provided feedback on both their absolute performance and the overall performance of their peers. The researchers accomplished this by drawing, once again, on both the personal factor of dimension relevance and the relational factor of similarity. They selected a task that was highly self-relevant to their similar and homogenous medical student participants, in the form of a multiple-choice quiz on medical knowledge that was required for these students' intermediate medical school examinations.

Beyond such suggestive but limited fMRI evidence, some recent EEG studies have specifically tested the effects of certain individual factors of social comparison and competition. Some research focused on the role of the *personal* factor of *social value orientation* (SVO) (Hu et al., 2017; Liu, S. et al., 2021; Qi et al., 2018)—a widely used measure of social preferences and motivations that categorizes decision makers into four basic orientations (competition, individualism, cooperation, and equality), which often are collapsed into two general "pro-self" and "pro-social" categories (encompassing the first and last two orientations, respectively) (Murphy & Ackermann, 2014).

For instance, Hu et al. (2017) measured ERP outcomes in a two-person gambling task in which participants, whose SVO they also assessed, had to select one of two down-facing cards with four potential sets of payoffs: a gain or a loss to the decision maker ("self-gain" or "self-loss") plus a gain or a loss to another, physically present but passive (confederate) participant ("other-gain" or "other-loss"). Results showed main effects of a more negative FRN for losses (both self-loss and other-loss) and larger P3 and Late Positive Component (LPC) for both self and other gains.

Hu et al.'s (2017) main contribution, however, is in finding significant main effects for SVO as well as two- and three-way interactions of SVO with outcomes: FRN was larger in the pro-social group than in the pro-self group (for both outcomes overall and each separate outcome) and showed a significant interaction between SVO and outcome; others' outcomes were significant for the pro-social but not the pro-self group. The interactions of SVO with the different outcome conditions further found the FRN more negative in the pro-self group for self-loss (vs. self-gain) but not for other-loss (vs. other-gain), whereas in the pro-social group it was more negative both for self-loss (vs. self-gain) and for other-loss (vs. other-gain). For the P3 amplitude, the results revealed a significant effect in the pro-social group for other-gain vs. other-loss only when their self-outcome was a gain, whereas in the pro-self group there were no P3 differences between other-gain and other-loss regardless of their own outcomes. The LPC, however, was larger in the prosocial group for other-gain vs. other-loss irrespective of their self outcomes, while exhibiting no significant difference between other-gain and other-loss in the pro-self group.

All in all, these rich findings reveal systematic ERP differences for pro-self vs. pro-social participants, suggesting that at the early stage of social comparison the pro-self primarily process their own outcome, whereas the pro-social attend to both theirs and the other's outcome. At the later stages of outcome evaluation, however, the pro-social—but not the pro-self—still engage in some processing of others' outcomes.

EEG studies also have begun examining the effects of the *relational* factors of social comparison. Liu, S. et al.'s (2021) study described above both increasing the dimension relevance (a personal factor) of their dot-estimation task to all participants by informing them that performance correlated with intelligence and directly manipulating the *relationship closeness* between participants and their comparison targets ("social distance" in these researchers' parlance). Specifically, the study recruited pairs of students, each of which was composed of friends of the same sex who had known each other for almost 17 months, on average. In one part of the experiment, participants completed the task with their friend; in another, they completed it with the stranger. Each part was divided into four blocks of 64 dot-estimation rounds. Participants received (manipulated) feedback on their and their partner's performance at the end of every block (consistent with the usual four self/other by gain/loss outcome options). Participants also completed self-reports of their emotional reactions each time they received outcome feedback.

To avoid repeating the basic ERP results described earlier, we discuss only the additional ERP effects related to Liu, S. et al.'s (2021) relationship closeness manipulation. Before turning to these, however, we note that the only significant effect found for the emotion self-reports was that participants were happier gaining money when the stranger lost than when their friend lost. This finding, which may appear intuitive, in fact represents a departure from the evidence of the broader behavioral literature, according to which relationship closeness intensifies social comparison and increases competitiveness, so participants should have preferred a downward comparison with their friend over the same with a stranger. One can speculate about possible (and not mutually exclusive) reasons for this discrepancy. The results may simply reflect participants' self-presentation concerns or experimenter demand; the friends may not have been sufficiently close to activate the relationship closeness factor; the strangers may have been perceived as belonging to a different social category, which would have increased social comparison concerns compared with the friends; there may be relevant cultural differences between the Chinese students in the study and the western participants in most relationship closeness studies, and more. What matters, however, is that this self-report result suggests caution when interpreting the related ERP findings to which we now turn.

Liu, S. et al. (2021) measured three ERP components that reflect different stages of outcome processing, adding to the FRN and the P300 discussed earlier a measurement of the N1—a negative component distributed in the parietal-central and occipital regions of the scalp that peaks earlier than the FRN (at approximately 130 ms after feedback onset). The N1 therefore reflects early, unconscious and automated, attention processing in reward-related feedback, and its amplitude increases with the processing of negative emotional stimuli and potentially threatening information (Liu, S. et al., 2021).

For the N1 amplitude, results showed a main effect of closeness, with increased negativity for outcome feedback when participants were paired with the stranger (compared to being paired with the friend), and no other main effects or interactions. The FRN also exhibited a main effect of closeness, being more negative for outcome feedback when participants were paired with the friend than when they were paired with a stranger. In addition, there was a significant three-way interaction for closeness by self-outcome by other-outcome. Participants exhibited more negative FRN for self-loss (vs. self-gain) when the friend gained but no difference between self-gain and loss when the friend lost. In contrast, when paired with a stranger, the FRN was more negative for self-loss (vs. self-gain) regardless of stranger's outcome. Finally, for the P300 there was again a significant main effect for closeness: this measure was larger for outcome feedback in the stranger pairing than in the friend pairing, with no other significant effects.

These findings from a manipulation of a relational factor of social comparison raise intriguing questions. Liu, S. et al. (2021) suggest the N1 result aligns with the general finding about the automatic attention given at this early stage to potentially risky or negative stimuli (such as the stranger). This finding may indicate that a relational factor, such as closenesss, only operates at later attention processing stages. Yet, both the main effect of the FRN—which was more negative for the friend—and the interaction showing a more negative FRN for self-loss only in the face of the friend's gain regardless of the stranger's outcome fit the expected effect of increased competitiveness with the friend due to closeness (although Liu, S. et al. (2021) offer a different interpretation). Similarly, larger P300 in the stranger pairing does not easily match the broader social comparison evidence on closeness.

A note on hyperscanning

Because hyperscanning studies capture simultaneous real-time data from two (and potentially more) participants, they can offer important contributions to the neuroscientific study of social comparison and competition. Indeed, Fliessbach et al.'s (2007) early dot-estimation study employed hyperscanning, which allowed the researchers to assess participants' reward processing of their relative payments in a more realistic, better-controlled, environment than in designs that scan only one decision maker. Both participants performed the same real task under identical conditions, simultaneously and repeatedly, a fact of which they were also both aware. Other neuroscience studies of social interaction support this advantage of hyperscanning methods that entail a comparison with a real interlocutor (Konvalinka & Roepstorff, 2012).

The potential benefits of hyperscanning have encouraged research on the neural correlates of competitive versus cooperative interactions, mostly focusing on brain synchronization (Balconi & Vanutelli, 2016b). For example, research demonstrates that brain synchronization occurs during cooperation but brain asynchronization during competition (Balconi & Vanutelli, 2017b; see also the earlier studies discussed by Konvalinka & Roepstorff, 2012), and fNIR studies showed enhanced inter-brain neural synchronization (INS) in the right superior frontal cortices during cooperation but not during competition (Cui et al., 2016). Liu and colleagues (2017) also found significant increases in INS across dyad members' right posterior superior temporal sulcus (pSTS) in both cooperation and competition conditions, whereas the right inferior parietal lobule (IPL) involved significant increases in INS in the competition condition (though this may have been due to the computerized game task).

Other hyperscanning research—in particular, studies conducted in recent years by Balconi and colleagues (for a detailed review see Balconi and Vanutelli, 2023)—offer intriguing findings that relate more closely to the social comparison perspective on competition. These studies usually employ the "sustained selective attention joint task," which allows researchers to induce competition between the scanned participants while controlling performance feedback. Besides its explicitly competitive design (participants are told scoring is based on their relative performance), the task also seeks to draw on the individual factors of social comparison by increasing the self-relevance of the comparison dimension (i.e., telling participants the task measures a cognitive skill that is used to screen for future professional career success) (Balconi and Vanutelli, 2023).

The sustained selective attention joint task also provides participants with positively manipulated downward comparison feedback. Studies found that this manipulation renders the PFC significantly more responsive (i.e., an increased oxygenated hemoglobin response) than prefeedback, implying a central role for the PFC in the positive self-perception that follows a downward comparison (Balconi & Vanutelli, 2017a), a conclusion that aligns with the single-participant fMRI findings on downward comparison discussed earlier.

Perhaps most intriguingly, Balconi and Vanutelli (2017a) also found that this downward comparison manipulation was followed by improvements in participants' cognitive and behavioral performance—that, in decreased error rates and response times—a phenomenon they dubbed the "enhanced brain effect" (Balconi & Vanutelli, 2017a). The researchers suggested this effect was due to the competitors' improved self-perception and further speculated about a "reciprocal effect" between the PFC, self-evaluation, and competitive performance. Perhaps the PFC modulates both the effect of superior performance in competitive settings on participants' self-evaluation and, somehow, the "reciprocal" performance-enhancing effect of improved self-evaluation (Balconi & Vanutelli, 2023).

A neuroscience research agenda

The preceding account of the developing neuroscientific literature on social comparison and competition demonstrates the substantial progress it has made in a relatively short time and, no less, the limitations of its current methods and resulting findings. A critical examination of this literature through the lens of our broader framework of social comparison before, during, and after competition further reveals numerous promising directions for future research. We discuss below these aspects of the neuroscience of social comparison and competition in turn.

Progress and limitations

Studies have identified neural correlates of social comparison generally and downward versus upward comparisons in particular and linked these findings to the brain's reward network and beyond (Kedia et al., 2014; Luo et al., 2018; Swencionis & Fiske, 2014; Yaple & Yu, 2020). These findings corroborate the long-standing behavioral evidence on the power of social comparison and demonstrate that this process can produce a stronger activation of the reward system than absolute payoffs do, even in objectively noncompetitive settings (Bault et al., 2011; Fliessbach et al., 2007) and, perhaps, even when social comparison is merely optional rather than inevitable (Wang et al., 2018).

Neuroscience fMRI research also offers important early evidence on the neural basis of learning from, and the attentional properties of, social comparison when it serves to reduce uncertainty in self-evaluation. These findings link decision makers' emotional responses to social comparison (Dvash et al., 2010) to brain regions associated with attributing mental states to others (Bault et al., 2011) and the processing of reward prediction and its errors (Takahashi et al., 2009), with some experimental designs even showing that such comparisons can shape later decision behavior (Bault et al., 2011; Liu et al., 2018). Results from EEG studies further indicate that social comparison information may be processed at both the primary, semiautomatic, stage (mainly upward comparisons) and the conscious, advanced, processing stage (mainly downward comparisons).

Functional MRI studies of social comparison and competition further provide tentative evidence for the role of some known individual factors of social comparisons, including the personal factors of individual differences and dimension relevance and the relational factor of similarity (Lindner et al., 2015), although they have manipulated these factors only infrequently (Moore et al., 2014; Takahashi et al., 2009). A number of recent ERP studies further explore the effects of the individual differences factor of SVO (Hu et al., 2017) and the relational factor of closeness (Liu, S. et al., 2021).

Besides expanding our knowledge of the neural foundations of social comparison and competition, moreover, the data generated through neuroscience methods can be used to enrich our conceptual understanding of these foundational behavioral phenomena. For instance, neuroscience designs commonly involve multiperiod tasks in which participants repeatedly engage in the same behavior, such as a simple game, a gamble, or a performance task. These designs generate many more repeated measurements than the designs used in the broader behavioral social comparison literature usually do. They also give researchers the opportunity to test for learning effects or other changes in judgment or decision behavior over these repeated measures, which only a few studies have done to date (Bault et al., 2011; Liu et al., 2018). This effort would also benefit from researchers developing a practice of sharing more granular experimental data that meta-analytical methods could later analyze to determine whether such effects are present in the existing evidence.

Related, neuroscience methods beyond those traditional fMRI studies that test one participant at a time promise additional insights into social comparison and competition. We noted some of these benefits—such as a more realistic setting for competition in which experiments can control and record the behavior of two (or more) parties to the interaction—in our discussion of hyperscanning findings. However, there is much more to learn from using this method. With respect to the intriguing INS phenomenon (Balconi and Vanutelli, 2023), for example, the literature would benefit from clarifying its function, causes, and consequences, relationship to social comparison and self-evaluation in competition, and more. Similarly, if replicated with the same or other neuroscience methods, hyperscanning evidence on the "enhanced brain effect" might indicate some broader performance benefits of biased self-evaluation following downward comparison (since the experimenters provided participants positively manipulated feedback) (Balconi & Vanutelli, 2017a); the same findings also raise the question of what effects might be produced by a modified "sustained selective attention joint task" that used accurate feedback or repeated upward comparisons.

Finally, the growing stream of EEG research also offers interesting possibilities. Earlier ERP studies focused on the FRN (Boksem et al., 2011; Qiu et al., 2010; Wu et al., 2012), but more recent designs began exploring additional measures representing different stages of outcome evaluation processing, adding the P3 and LPC (Hu et al., 2017) or even the N1 amplitude (Liu, S. et al., 2021) to the commonly measured FRN. By offering such high temporal resolution, these measures can help researchers to identify differences between upward and downward comparisons or the differential effects of the factors of social comparison, as we explain further below.

Notwithstanding their accomplishments and promise, however, current neuroscience studies of social comparison and competition exhibit certain methodological limitations, partly due to present technological constraints. One case, already discussed, concerns the virtually exclusive reliance of neuroscience studies on the reaction method (Kedia et al., 2014; Luo et al., 2018; Swencionis & Fiske, 2014), with the resulting limitation of the range of research questions this literature examined.

Another straightforward constraint relates to the limits to the simultaneous study of multiple decision makers' neural activity, an important research area for the multiparty interactions that social comparison and competition often involve. Traditional fMRI studies that measure the neural activity of a focal decision makers who believe they are facing real competitors (as when interacting via computer terminals, Qi et al., 2018) or who physically face a confederate (Hu et al., 2017) or an actual competitor (Liu, S. et al., 2021) offer a partial response to this constraint. Even more promising in this respect are hyperscanning studies that simultaneously measure two competitors and already produced intriguing results (Balconi and Vanutelli, 2023), although they cannot simultaneously measure larger numbers of participants.

Future research directions

The conceptual framework described and applied to the broader behavioral literature in the first portion of this review offers a rich set of further research questions that extant neuroscience studies have either overlooked or only partially addressed. While we occasionally alluded to these in the course of this review, this section examines them systematically, considering social comparison before, during, and after competition.

Before competition

The Social Comparison Cycle of Competition framework (Garcia, Reese, & Tor, 2020) makes apparent that social comparison can take place before competition, as decision makers seek to reduce uncertainty before deciding whether or how to act competitively or to enter a formal competition. However, our literature review was unable to identify neuroscience studies addressing this question, with the possible exception of Wang et al.'s (2018) incidental reporting of increased anticipatory attention just before task onset during their multi-trial stop-watch game. Specifically, this EEG study found enlarged stimulus-preceding negativity (SPN) in the two-player condition compared to the single-player condition (which also aligned with participants' self-reports about their increased interest, enjoyment, effort, and motivation to win in the former condition).

The paucity of evidence before competition may be due in part to the neuroscience literature's reliance on the reaction method discussed previously, yet important research inquiries could still be explored using extant methods, such as by treating the individual factors of social comparison before competition as independent variables. This approach would be most straightforward for personal factors, like those individual differences in SCO (Gibbons & Buunk, 1999) that have been linked to trait competitiveness (Liu, Z. et al., 2021) and the propensity to act competitively (Reese et al., 2022), or even the SVO measure that a number of EEG studies have already employed (Hu et al., 2017; Liu, S. et al., 2021). However, rather than expose all experimental participants to the same task as extant studies do, researchers could require participants to choose between objectively competitive and noncompetitive tasks, or even between tasks that allow for social comparison and similar tasks that do not offer that possibility. Wang et al.'s (2018) design that offered participants the option of social comparison takes a first useful step in that direction, but even that study did not offer decision makers a path without the possibility of comparison, nor did it report any measurements of participants' neural activity before competition.

Another aspect of the study of social comparison before competition that received substantial attention in the behavioral literature but limited interest to date from neuroscience researchers is the matter of judgmental biases, such as the illusory superiority findings discussed earlier (Dunning, 2023; Zell et al., 2020). One study sought to identify the neural correlates of the "above average" bias—a form of illusory superiority—finding that the extent to which participants viewed themselves as "above average" was negatively correlated with OFC and, to a lesser extent, with dACC activation (Beer & Hughes, 2010). However, the researchers used a pure judgment task in a noncompetitive, nonsocial setting, which required comparisons to a hypothetical group norm (an average peer) rather than to a concrete target individual. These characteristics render Beer and Hughes's (2010) results (and similar ones on social cognition biases more generally) intriguing but in need of further exploration for present purposes.

During competition

Where social comparison during competition is concerned, the neuroscience literature is somewhat more developed. Earlier fMRI findings that established the brain regions involved in social comparison and competition often measured participants' brain activity during competition. Decety et al. (2004), for example, engaged participants in a game with confederates that had two versions—a cooperative and a competitive one—finding hemodynamic changes in the right superior frontal gyrus, the right inferior parietal lobule, and bilaterally in the mPFC, when contrasting activation by competition versus cooperation.

Nevertheless, most studies of brain regions generally associated with social comparison and competition measure decision makers' outcome evaluations (Kedia et al., 2014; Luo et al., 2018; Swencionis & Fiske, 2014), rather than social comparison during competition and *before* the outcomes generated by its resolution. One set of exceptions to this general rule concerns the promising use of hyperscanning and, in particular, the INS findings of studies employing this method (Balconi and Vanutelli, 2023); yet, as already noted, this phenomenon has not been thoroughly explored, nor has it been linked to social comparison processes to date.

The same common focus on final outcome evaluations is reflected in EEG studies (Hu et al., 2017; Qi et al., 2018; Sun et al., 2022), whose repeated measurements during multitrial tasks could be adapted to the study of social comparison during competition. In fact, one might characterize designs, such as Liu, S. et al.'s (2021), which measured ERPs following feedback at the conclusion of each of four blocks of trials that comprised the experimental task, as measuring "during competition." Researchers could use similar designs deliberately to study reactions to feedback on concrete comparison events or competitively significant (manipulated or organic) developments that occur in the course of competition, before the task is completed and final outcomes are resolved.

More generally, experimental paradigms testing social comparison during competition could offer many factors—individual or situational—for neuroscientific exploration. Such paradigms might measure indicators of reactions to social comparison information in the course of the task, the allocation of attentional resources to the task itself, or to social comparison information during competition, and more. Once established, these paradigms could draw as independent variables on the individual factors of social comparison, including both personal factors—such as comparisons on dimensions that are more or less personally relevant or individual differences that render decision makers more or less competitive—and relational factors, from the familiar target similarity, through the less familiar relationship closeness, to the unfamiliar rivalry based on a shared history of competitive interactions (Converse et al., 2023).

In the same vein, the study of the situational factors of social comparison during competition offers further fertile experimental terrain, because these factors are yet to receive concerted neuroscientific attention and are straightforward to manipulate. For instance, it is simple to manipulate participants' incentive structures (e.g., more vs. less competitive payoffs), the framing of different social categories (i.e., ingroup vs. outgroup competition), the setting of competition in the shadow of a ranking scale and participants' respective locations on that scale, the number (N) of competitors, etc.

Finally, the behavioral findings described earlier raise important questions about the nature of bias in social comparison during competition and its neuroscientific measurement. To wit, although the effects of illusory superiority might also manifest during competition, social comparison research in this area focused instead on the misalignment of individuals' preferences and their competitive behavior. A case on point is the research described earlier that shows how, when exposed to social comparison information during competition, decision makers can lose sight of their own goals (e.g., profit-maximization or mastery) in the pursuit of relative positional advantage (Van Yperen & Leander, 2014).

Behavioral findings of this sort raise intriguing questions for neuroscience, such as whether it is possible to identify neural correlates of a bias that consists of a purported misalignment between decision makers' goals and their use of social comparison information or actual competitive behavior, whether researchers would benefit from combining behavioral and neural measures in this context, or which types of measures would be most useful here.

A similar, yet distinct, set of questions arises with respect to the potentially biasing influence of the situational factors of social comparison—such as the number of competitors (N) or social category fault lines—during competition. The possibility of decision error arises not from conflict between preference and behavior, but rather from how situational factors can shape competitive behavior in ways that fail to align with its benefits (e.g., expected payoffs) to the decision maker. Hence, in these instances, it may be worth considering whether neural measures can associate situational factors with discrepancies between measures of attention or the expenditure of other cognitive resources and, conversely, the objectively expected payoffs from competition.

After competition

Neuroscience studies have devoted substantial attention to social comparisons after competition. Indeed, we examined the sizable and developing literature on relative outcome evaluations more generally and downward versus upward comparisons specifically (Kedia et al., 2014; Luo et al., 2018; Yaple & Yu, 2020). Notwithstanding the more developed state of the art, however, our assessment of the literature revealed numerous unexplored areas that merit future inquiry, beginning with research on comparison direction but mostly focusing on the factors of social comparison and competition, including both the better-studied individual factors and, in particular, those largely unexplored situational factors.

Like other aspects of the literature, the study of comparison direction, despite being the most advanced of all areas of neuroscience social comparison research, still suffers from its reliance on reaction method studies. Comparison direction experiments measure participants' outcome evaluations, typically comparing responses to upward versus downward comparisons or of one of these comparison directions to a lateral comparison (i.e., equal payoffs or another equal outcomes) (Luo et al., 2018; Yaple & Yu, 2020). However, researchers could deploy similar designs as (somewhat constrained) selection studies, making both upward and downward comparisons (and perhaps even lateral comparisons with equal outcomes) available outcomes of the experimental task. Such studies could require participants to select which social comparison information to obtain (if any), measuring the neural correlates of both the selection process and the outcome evaluation that follows. Taking this approach would not just link the neuroscience literature to the broader behavioral evidence on comparison direction (Gerber et al., 2018) but also reveal whether the neural patterns associated with downward or upward comparisons remain the same or differ when individuals select into a given comparison direction rather than unavoidably experience it.

Turning to the individual factors of social comparison, we found that a handful of studies already employed the personal factors of dimension relevance and certain individual differences and the relational factors of similarity and relationship closeness. However, such studies are few and far between, and further research clearly is needed to clarify whether these factors exert systematic neural effects after competition. In addition, other individual factors—including some important individual differences variables (e.g., social comparison orientation) or the relational factor of rivalry—remain unexplored in this context.

Furthermore, the rich opportunities for neuroscience research of the situational factors of social comparison after competition remain wholly untapped. These are the same factors already discussed in our proposed neuroscience research agenda during competition, except that researchers who study outcome evaluation after competition need not develop new paradigms. Instead, they merely need to use existing paradigms to test for the effects of situational factors such as incentive structures, social categorization, proximity to meaningful comparison standards, or the number of competitors (N).

Finally, we should note the paucity of evidence currently available on the effects of outcome evaluation on later judgment and behavior. The few available studies in this area were able to link social comparison to later risky decision making (Bault et al., 2011; Liu et al., 2018), but further inquiry clearly is needed to establish a better neuroscientific understanding of the effects of social comparison on risk taking after competition as well as on competitors' learning from competition more generally and its impact on their propensity to reenter future competitions and their behavior during such competitions.

Conclusion

This review focused on social comparison and competition, showing how the extensive behavioral evidence and conceptual frameworks used to organize it can inform neuroscience. The first major section offered illustrative findings on social comparison before, during, and after competition while highlighting throughout the self-evaluation function of the social comparison process, the important role of its factors—both individual and situational—in variously facilitating or inhibiting competition. This section also described the complex reality of social comparison as an adaptive and relatively efficient means for self-judgment under uncertainty that nevertheless contributes to biases and likely decision errors in competition. Armed with this understanding, the second major section examined the developing neuroscience literature on social comparison, its methods, and findings. A critical assessment of this literature through the lens of our behavioral framework and evidence in the third and final major section of this review offered a deeper and richer account of the accomplishments and limitations of neuroscience in this area. Importantly, this assessment also revealed a broad range of neuroscientific research questions about social comparison before, during, and after competition that await exploration.

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